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THE DESIGN AND FABRICATION OF A COMPOUND DIE TO MAKE HEXAGONAL WASHER

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ABSTRACT

Many parts and components used in mechanical industry are manufactured by cold pressing operations. Die is the main tool in these operations. There are different types of dies like progressive die, compound die and combination die.

This paper presents design and fabrication of a compound die which combines blanking and piercing operations. Design and development of compound die is one of the important phases in sheet metal working. The small error in the design can result in heavy manufacturing losses through die failure, part geometry distortion and production risk. Assembly of all the die elements is another task where use of accurate measuring instruments for alignment of various tool elements is important. In the present work, a compound die for production of a hexagonal washer of M15 bolt has been designed and developed. The 2D modelling of the compound die has been done using solid works software. This press tool has been tried out on a fly press. The components produced are to the required dimensions.

KEYWORDS: Cold Pressing, Progressive Die, Compound Die, Combination Die, Blanking, Piercing, Solid works & Fly Press

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Original Article

INTRODUCTION

Sheet metal working is an important manufacturing process for many industries producing kitchen utensils, home appliances, electronics, automobiles, toys, furniture etc. Most of these products have sheet metal casings that are made by cutting and forming the sheet metal. Some of the basic sheet metal operations are blanking, punching (Piercing), drawing and bending.

Blanking is a cutting process in which a piece of sheet metal is removed from a larger piece of stock by applying required shearing force. In this process, the piece removed, called the blank, is not scrap but rather the desired part. Blanking can be used to cutout parts in almost any 2D shape, but is most commonly used to cut work pieces with simple geometries that will be further shaped in subsequent processes. Punching is a process in which the punch removes a portion of material from the larger piece or a strip of sheet metal. If the small removed piece is discarded, the operation is called punching, Figure1 shows difference between blanking and piercing,

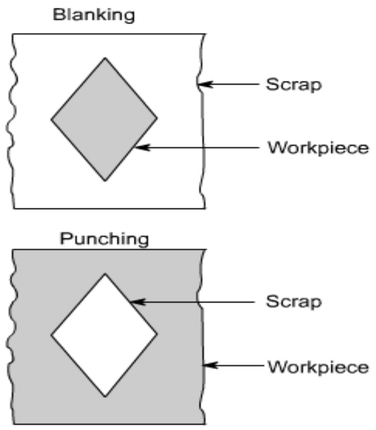

Figure 1: Blanking Vs Piercing Operations

Die is the main tool used for these press working operations. It is a specialized tool used to cut or shape materials into pre-determined shapes. There are different types of dies- simple die, progressive die, compound die and combination die.

Simple die performs only one operation like blanking or punching or drawing etc. The die which performs two or more operations simultaneously at different work stations in a single stroke is known as a progressive die. Compound die performs two or more cutting operations, typically piercing and blanking at single station in single press cycle. The advantage of a compound die is the high and unsurpassed mechanical accuracy of a single step process.

Die design is an important part of press metal working. Many parameters have to be considered while designing the dies for various sheet metal working operations. The construction of compound die is more complicated than progressive die. A common characteristic of compound-die design is the inverted construction, with the blanking die on the upper die shoe and the blanking punch on the lower die shoe. Figure 2 shows the compound die assembly and its various parts.

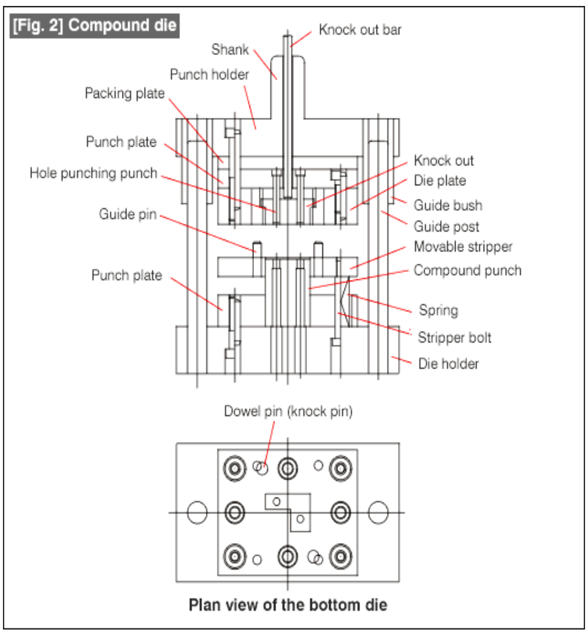

Figure 2: Compound Die Assembly

In this paper a compound die combining blanking and punching operations is designed and fabricated to make a hexagonal washer of M15 bolt. 2D modeling is done using SOLIDWORKS software.

METHODOLOGY

Figure 3 shows a simple component called hexagonal washer for which a simple compound die needs to be designed.

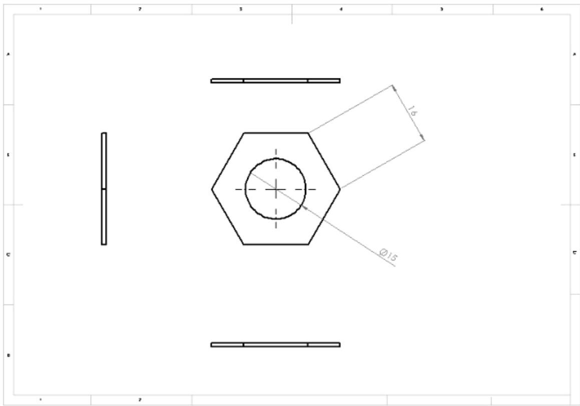

Figure 3: Hexagonal Washer to be Made

The specifications of washer to be made are given in the table 1.

Table 1: Specifications of Washer

S. NO	Description	Specification
1	Component name	hexagonal washer
2	Type of tool	compound tool
3	Sheet metal material	mild steel
4	Sheet thickness	1mm
5	Press tonnage	8 tons

Design of Compound Die

As far as sheet metal working is concerned, the die design is a very important aspect. Many parameters have to be considered while designing the dies for various sheet metal working operations.

Selection of Materials

Press tools are generally made using HCHCr, Steel alloys with high carbon. But before that based on many factors like cost, strength, hardness, strain and many parameters selection should be made. The materials used are D2, EN31. Mild Steel is used as supporting plate. Apart from that, materials like the D3, high carbide materials, chromium steels and high speed steels are also used.

Design and Optimization of Punch and Die

Some thumb rules and standards are used for die and punch size calculation. The force required for blanking and punching is also calculated. Optimization is carried out by selecting different materials for die and punch. By selecting different material for die and punch we get a variety of choices for choosing particular material. On the basis of properties of different material we will optimize the specific material for die and punch.

Calculation of Press Capacity

We have press capacity =Fmax *C

Where C=1.1 to 1.5 for normal profile

C=1.25 to 1.75 for $\frac{d}{t}$<2

Presscapacity=Fmax*C

=8 tons*9.81*1.5

=8*1000*9.81*1.5

=11720N

Energy of press =Fmax*C*punch travel

=8000*9.81*1.5*8

=94176 N-m

Minimum Diameter of Piercing

We have piercing pressure= $(\tau)*\pi*dl$ strength of the punch=$\sigma*\pi\frac{d^{\wedge}2}{4}$

If we equate the piercing and strength of the punch we obtain the minimum diameter of piercing

ie$(\tau)*\pi*dl=\sigma*\pi\frac{d^2}{4}$

d=$\frac{(\tau)}{\sigma}$4*t

d=2t (σ=2τ)

as our compound die piercing punch diameter is 15

so it si safe

ie 15mm>2t

15mm>2mm

Minimum size of punched holes depending upon their shapes are as follows:

0.7 to 1.2t for soft steel

0.9 to 1.5t for steel

1.75 to 2t for Ti alloys

0.6 to 0.9t for brass and copper

0.5 to 0.8t for zinc

0.4 to 0.7t for Bakelite

0.3 to 0.6t for cardboard and paper

Die Block Thickness

Die block thickness can be calculated as follows

Die block thickness =T=$\sqrt[3]{F}$ where F is in tons

=$\sqrt[3]{8}$=2mm

die block thickness is taken as 20 mm

Relief Angle

As already mentioned relief angle should be $\frac{1}{4}^0$to 1^0 for small die

1^0 to 2^0 for average die

2^0 to 3^0 for large die

As our compound die is average die relief angle should be between $1^0$and 2^0

So relief angle for die is equal to $\tan^{-1}\frac{1}{40}$

=1.432 so it is between$1^0$to 2^0

Area of Die Opening Border

Table 2: Area of Die Opening Border

Maximum Cutting Force (KN)	Area between Die Opening Border (cm^2)
200	3.25
500	6.5
750	9.75
1000	13.00

Area of die opening border for various cutting forces are shown in the table 2.

Fastening of Die Block

Screw diameter =0.5 t for T<19mm

=0.4t for T>19mm

We took it as 8mm which is greater than 0.4t for the sake of safety and alignment purpose

Punch Length

Maximum length of punch is equal to

L=$\frac{\pi d}{8}$sqrt($\frac{Ed}{\tau t}$)

=$\frac{\pi * 15}{8}$sqrt($\frac{2*100000*15}{400}$)

=510mm

But generally punch length is taken as 60 to 85 mm. So 64 mm is taken as length of the punch.

Design of Spring

Maximum force on spring is should be as follows

Fmax> 1.5*$\frac{Fstr}{i}$ (i=1)

Where Fstr=stripper force

=0.05 to 0.08*F

=0.07*8000

=5493.6N

Fmax=1.5*$\frac{5493.6}{1}$=8240.4

Fmax=8240.6N.

Calculation of Punching Force and Blanking Force

Punching

Punch size =15mm+allowances

=15+0.05

=15.05mm

Die size=punch size +2c

Where c is clearance

=15.05+2

=15.25mm

Punching force=πdtτ

Where d is diameter of punch

t is thickness of metal sheet

τ is shear force

punching force=π*15.05*1*400

=18912.38N

Blanking

Blanking force=perimeter *thickness*shear force

=(perimeter of hexagonal-perimeter of

circle)*thickness*shear force

=(6*side of hexagon –πd)*1*400

=(6*16-π*15)*400

=48.876*400

=19550.44N

D Modeling of the Compound Die

The 2D modeling of the die is made using

Solid Works

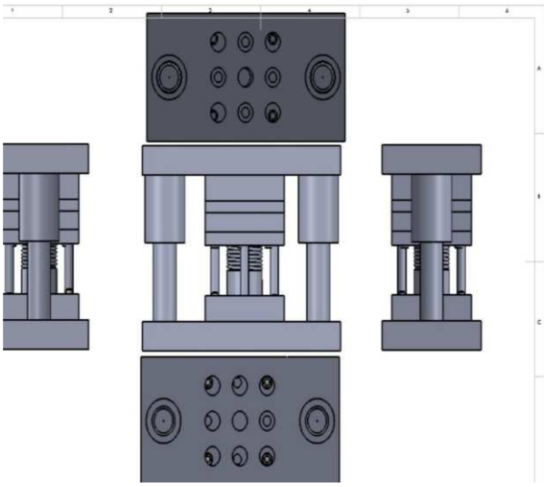

Figure 4: 2D Model of Compound Die

The five views of compound die in the first angle projection are shown in the figure4.

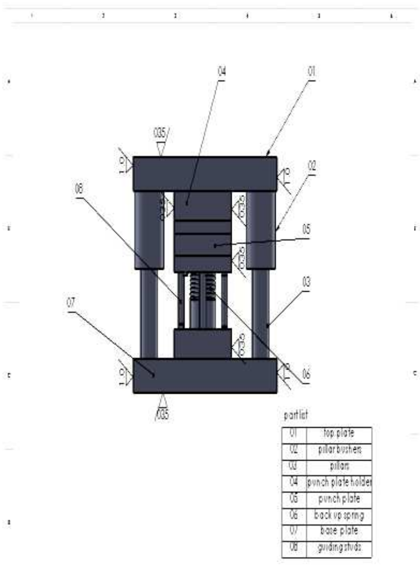

Figure 5: Surface Roughness Values and Parts List

Parts list and surface roughness values are shown in the figure5.

Fabrication of Compound Die

Operations carried for each part are shown below:

Top Plate

- Milling
- Bench work
- Drilling
- Surface grinding

Base Plate

- Milling
- Bench work
- Drilling
- Surface grinding

Guide Bushes

- Turning
- Cylindrical grinding
- Heat treatment

Figure 6: Guide Bushes

Guide Pillars

Figure 7: Guide Pillars

- Turning
- Cylindrical grinding
- Heat treatment

Guide bushings and guide pillars shown in figure 6 and figure 7 are not only useful for aligning the die members but also reduce the die setup time.

Punch Holder

Figure 8: Punch Holder

- Milling
- Bench work
- Surface grinding
- CNC milling

Die Plate

Figure 9: Die Plate

- Milling
- Bench work
- Drilling
- Surface grinding
- Heat treatment

- CNC milling

Punch holders and die plate are shown in figure 8 and figure 9.

Back Plates

- Milling
- Bench work
- Drilling
- Surface grinding

Blanking Punch

- Lathe
- Cylindrical grinding
- Profile grinding
- Heat treatment

Piercing Punch

- Lathe
- Cylindrical grinding
- Profile grinding
- Heat treatment

Selection of Press and Testing of the Die

Figure 10: Compound Die Set

The fabricated compound die set shown in the figure 10 has been tested on a press.

The selection of suitable press depends upon various parameters. The following factors are considered while selecting the press:

- Force required to cut the metal
- Stroke length
- Size and type of die
- Method of feeding and size of sheet blank
- Shut height
- Type of operation

Table 3: Blanking and Punching Forces

Punch force	16742.8
Die block thickness	20mm
Punch length	64mm
Punching:	
Punch size	15.05mm
Die size	15.25mm
Punching force	18912.38N
Blanking force	19550.44N

Table 3 shows the sizes of punch & die and blanking &punching forces which are considered while selecting the press.

A fly press of suitable capacity shown in the figure 11 is selected for testing the die.

Figure 11: Fly Press used for Testing the Compound Die

The hexagonal washer shown in the figure 12 is produced successfully by the compound die on a fly press.

Figure 12: Hexagonal Washer Made using the Developed Compound Die

CONCLUSIONS

Compound die for the required hexagonal washer is designed, fabricated and tested successfully on a fly press of suitable capacity. The hexagonal washer made on the die is to the accurate dimensions. This die is being used successfully in the Metal forming Lab of Chaitanya Bharathi Institute of Technology, Hyderabad.

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